A Unique View on Carbon Dioxide Emissions around the World

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Abstract: Carbon dioxide (CO_2) emission substantially contributes to the global warming. Its anthropogenic effects accounts for about two-third of the overall environmental pollutions. Fossil fuels (coal, petroleum and natural gas) combustion is responsible for most of the human-made CO_2 release. In this article, we present and compare, in several new and unique ways, the CO_2 emission in selected populated countries in all continents, which are known as highly active in fossil and/or renewable energy production / use. They include Algeria, Australia, Brazil, China, Iraq, Italy and USA. We also include the State of Illinois, USA, which is the outmost active state in fossil and renewable energy production and use, and is a pioneer state in dealing with carbon dioxide control and sequestration. By comparing the above regions with the related data of the entire world it reveals a great deal about the activities going on around the world. This may provide policymakers and environmentalists a more proper roadmap in dealing with carbon dioxide emission control policy and planning.

Keywords: Carbon dioxide, CO_2 emission, Environmental pollution, Fossil fuels, Global warming.

1. INTRODUCTION

Global warming is one of the critical issues in our today life. It affects all the world regions and the problem is growing larger and larger. Currently, it has attracted more attention than ever due to the evidence that it is mainly anthropogenic, resulting from the influence of human beings on nature. The main impacts of global warming are the increase in the Earth's environmental temperature, oceans warming and the rise in oceans water levels due to melting of the Arctic ice [1-3].

Generally, there are many parameters that may affect climate change. They may be divided into two groups: natural and anthropogenic. The natural parameters include Earth's revolution around the sun and the Earth's inclination, decompostion, ocean release and respiration.

The greenhouse gases (GHGs) are considered the paramont contributor to the anthropogenic global warming. The GHGs are defined as the gases that absorb the sun's radiation and convert it to heat. The known greenhouse gases are carbon dioxide, methane, water vapor, nitrous oxides, and halogenated compounds [4]. Concentrations of these compounds in the atmosphere have been increasing significantly over the past century. Human activities are the main cause of rising the emission of these gases [5]. In Table 1 we report a comparison of concentration of the GHGs in 2015.

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The high concentration of CO_2 makes it the major driver of the global warming due to the presence in the atmosphere in a much larger amount than other GHGs. CO_2 atmospheric concentration has increased from about 277 ppm in 1750, the beginning of the industrial Era, to 404.48 ppm in December 2016 [6, 7]. The increase in CO_2 concentration levels started initially from deforestations and later, beginning with 1920, mainly from combustion of fossil fuels.

Currently, about 60% of the overall GHG emissions, which is mostly carbon dioxide, is a result of fossil fuels combustion [8, 9]. Based on the current trend, calculations show that CO_2 emission will increase by about 150% in 2040 above its levels in 1980 without implementation of any mitigation plans [10]. The temperature increase due to the gas emission is estimated to be different for different regions. The climate response for the CO_2 emission has a range from 1^oC per 10^{12} ton of CO_2 in the ocean regions to more than 5^oC per 10^{12} ton of CO_2 in the Arctic regions [11].

In the present paper, we report our comparative studies on the carbon dioxide emission in the world and selected regions of every continent, which include Algeria, Australia, Brazil, China, Iraq, Italy, USA and the State of Illinois in USA. We chose the United States and China because they are the major CO_2 releaser countries in the world. Australia was chosen to symbolize Australia continent. Italy emission is studied to represent the European countries. We chose the countries Iraq, Algeria and Brazil since they are rather proper representations of the developing countries in the Middle East, Africa, and South America, respectively. We chose the State of Illinois since it is a

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pioneer state in the United States to achieve sustainability in energy and environment [12, 13]. Various analysis and comparisons which we have made in the CO_2 emissions of the above-mentioned regions and the world reveal a great deal about what is going on around the world and what we should expect if the ongoing trends continue. We present the amounts of CO_2 emitted by each region and the sources of the emissions. We focus on the fossil-fuels-related emission because it is the main source for CO_2 release. We also present various emission intensities which include emission per unit electricity, per population, per unit economy using exchange rates, and emission from each sector. We also report predictions and analysis for the emissions for up to the year 2040.

2. CO_2 EMISSION

One of the major problems associated with the use of fossil fuels is production and release of carbon dioxide (CO_2) to the atmosphere, as a result of which its concentration in atmosphere is increasing at an accelerating rate from decade to decade.

Carbon dioxide that is emitted due to the fossil fuels combustion drives the major role of the anthropogenic contribution to climate change with a share of about 60% of the overall GHG emissions [14]. The current emission level of CO_2 is above 35 billion metric tons annually, as shown in Figure **1**. Globally, CO_2 emission from fossil fuels has been increased by about 83% during 1980-2014.

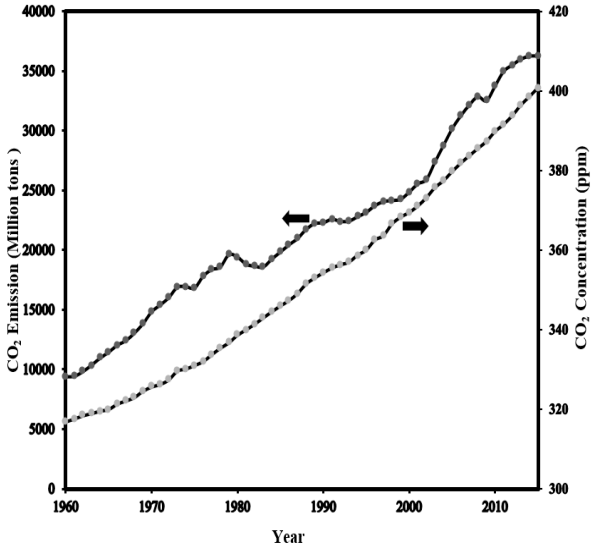

Figure 1: CO_2 emission and concentration in the atmosphere worldwide from 1960 to 2015 (Data from [10, 15]).

The level of CO_2 concentration in the atmosphere exceeded 400 ppm in 2015 for the first time since the record keeping began [5, 7], as shown in Table **1**, while the maximum safe level of CO_2 concentration is 350 ppm. As the CO_2 concentration rises, the temperature of the Earth surface increases. The global average temperature in 2015 increased by more than 1^oC above the period of 1850-1990. Per the Intergovernmental Panel Climate Change (IPCC), over 90% of the global warming caused by anthropogenic (human) activities especially by burning fossil fuels [16]. According to the U.S. National Aeronautics and Space Administration (NASA) and the U.S. National Oceanic and Atmospheric Administration (NOAA), Earth's surface temperature in 2016 was the warmest since 1880, when the record keeping started [6].

Table 1: Concentration, in Part per million (ppm) of Greenhouse Gases in the Atmosphere in 2015 (Data from [5])

Greenhouse gas	Chemical Formula	Concentration
Carbon dioxide	CO_2	400.83
Methane	CH_4	1.786
Nitrogen oxide	N_2O	$3.27x10^{-1}$
PFC-14	CF_4	$8.2x10^{-5}$
Nitrogen tri-fluoride	NF_3	$1.24x10^{-6}$
Ozone	O_3	326.2 DU (*)

(*) Thickness of ozone layer in Dobson unit. One DU is defined to be 0.01 mm thickness of at standard conditions.

2.1. Emissions in Selected Regions

CO_2 emission data for the selected regions and the world we use here and reported in Figure **2** was extracted from the International Energy Agency (IEA) report, which is released in December 2016 [10].

In studying the emission data, which is shown in Figure **2**, we observed the following:

CO_2 worldwide emission level has increased from about 17.7 billion tons in 1980 to about 32.4 billion tones in 2014. During the last three decades, CO_2 emission has doubled. The emission value has increased by 5.4 billion tons between 1980 and 2000, while it has increased by about 9.2 billion tons from 2000 to 2014. The emission increase above the preceding year was about 0.8% in 2014, 1.7% in 2013 and about 2.4% in 2000. The increase in 2014 above 2013 is the smallest in the last decade, which has an increase rate of 4% on average.

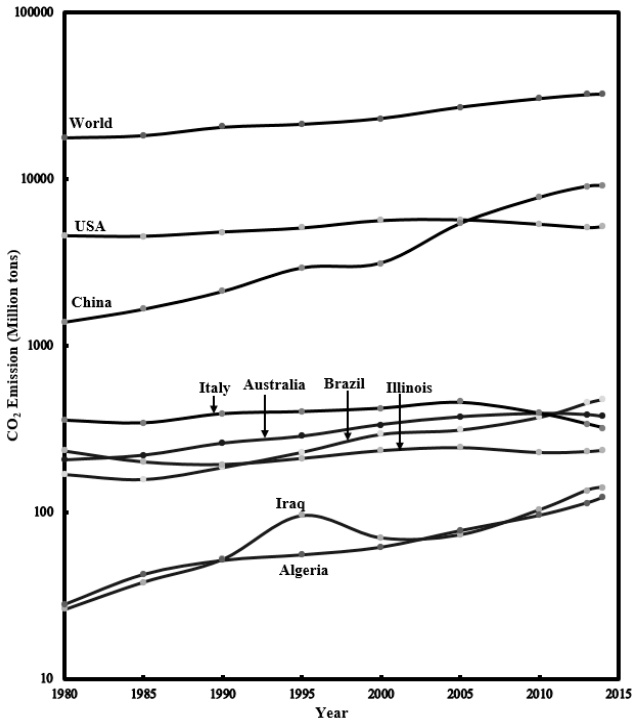

Figure 2: CO_2 Emission for the world, seven countries and the State of Illinois, USA for the 35-year period 1980 to 2014 (Data from [10]).

The United States emitted about 5.1 gigatons of CO_2 in 2014 which accounts for nearly 16% of overall global anthropogenic emission. In 2014, the emission by the U.S. has increased by 8% above its level in 1990. However, it decreased by about 8.2% below the emission level at 2000.

China is holding the first position for CO_2 emission among all the countries since 2007 due to the rapid growth in its energy consumption. China's emission witnessed a significant increase since 2000 and exceeded the U.S. release, which is ranked the second emitter in the world. In 2014, CO_2 release by China reached about 9.08 gigatons which is accounted for about 28% of the global anthropogenic emission. China's emission has dramatically increased during 1990-2014 by 338%.

From Figure **2**, it is obvious that in all the selected countries and worldwide CO_2 emission has increased during 1980-2014 period except in Italy, which has decreased by about 10%. The developing countries emission have increased by rates much higher than the developed countries. China, Iraq, Brazil and Algeria increasing rates were 563%, 442%, 344% and 184%, respectively. On the other hand, USA, Australia and Illinois increasing rates were about 14%, 81% and 0.8%, respectively.

2.2. Emissions Sources

In Table **2** we report sources of CO_2 emission in the world, the seven selected countries and the State of Illinois in USA. According to Table **2**, CO_2 emissions from all the regions are mainly due to use of fossil fuels. Coal, which has several types with different emission coefficients as shown in Table **3**, was responsible for release about 14.87 billion tons (45.92%) of CO_2 to the atmosphere worldwide in 2014, while oil emitted about 10.97 billion tons (33.89%) in 2014. Natural gas CO_2 emission in 2014 worldwide was nearly 6.4 billion tons (19.65%). The emission from coal, oil and natural gas use accounted for about 96.6% of the overall CO_2 emission worldwide in 2014.

China has the same CO_2 emission distribution that the world has. Coal consumption in China was responsible for about 83% of overall CO_2 emission in 2014. Oil consumption in USA, Brazil, Italy, Iraq and Algeria emitted more than the other fossil fuels in 2014.

Table 2: CO_2 Emission, in Million Tons (% in Parenthesis), from various Fossil Fuels in 2014 (Data from [10])

Region	Coal	Oil	Natural gas	Other	Total
World	14,871.4 (45.92%)	10,973.4 (33.89%)	6,362.8 (19.65%)	173.5 (0.54%)	32,381
USA	1,698.7 (32.81%)	2,035.8 (39.33%)	1,420.1(27.44%)	21.6 (0.42%)	5,176.2
China	7,569.3 (82.86%)	1,195.7 (13.09%)	336.3 (3.68%)	33.6 (0.37%)	9,134.9
Australia	167.79 (44.89%)	131.77 (35.25%)	73.61(19.70%)	0.61 (0.16%)	373.78
Italy	51.8 (16.2%)	145.6 (45.54%)	117.23 (36.67%)	5.09 (1.59%)	319.71
Brazil	68.25 (14.33%)	330.1 (69.35%)	77.67 (16.32%)	-	476.02
Iraq	-	128.58 (91.17%)	12.45 (8.83%)	-	141.03
Algeria	0.23 (0.19%)	53.99 (43.92%)	68.71 (55.89%)	-	122.93
Illinois	96 (41.08%)	79.4 (33.98%)	58.3 (24.94%)	-	233.7

Coal consumption in China, Australia and Illinois emitted more than the other fossil fuels in 2014. Natural gas consumption in Algeria emitted more than the other fossil fuels in 2014, while almost 100% of fossil fuel consumption in Algeria were natural gas and petroleum.

Table 3: Carbon Dioxide Emission Coefficients from Different Coal Ranks [17]

Coal Rank	Emission Coefficient [kg/MMBtu]
Bituminous	93.40
Anthracite	103.54
Lignite	96.36
Sub-Bituminous	97.02

Even though the renewable and nuclear energy sources are witnessing a growth in recent years, contribution of fossil fuels for energy production was unaffected over the last four decades [10]. It is expected that CO_2 emission will keep increasing in future years unless some major changes happen around the world.

2.2. Emission Indicators

The total CO_2 emission for the world and each region, as reported above, show a good picture of CO_2's tremendous effect to the global warming and the responsibility share of every region. To have a more detailed perspective on CO_2 emission we report four indicators that we use for emission comparison of various regions. They include emission per sector, emission per kWh electricity generation, emission per capita, and emission per GDP:

2.2.1. Emission per Sector

Studying the emission from each sector may enable the policy makers to know where to focus in order to mitigate CO_2 release. In Table **4**, we report the contribution percentages of each sector in overall CO_2 emission for the World, seven selected countries and the State of Illinois in 2014.

We make the following observations by analyzing Table **4**:

Energy-production sector emitted more than any other sector in all the selected regions, except Brazil. Emission from the energy sector accounted for about half of the global anthropogenic CO_2 release in 2014. The World-wide energy use has increased significantly due to the growth of the world population and economic developments. The energy sectors in China, Australia and Iraq, are responsible for more than half of the emission in all these regions. These countries also emitted CO_2 from energy sector more than the average world emission value.

Table 4: CO_2 Emissions Percentage per Sector for each Region in 2014 (Data from [10])

Region	Energy	Transportation	Industrial	Other sectors
World	47.27	23.31	19.24	10.18
China	52.32	8.63	31.64	7.41
USA	45.99	33.4	8.65	11.96
Australia	58.35	24.75	11.5	5.4
Italy	35.55	32.96	11.19	20.3
Brazil	26.3	44.74	20.61	8.35
Iraq	65.11	20.57	7.87	6.45
Algeria	38.81	35.31	8.3	17.58
Illinois	37.55	27.85	16.96	17.64

Transportation is another important sector in CO_2 emission in the selected regions. It accounted for about 23% of the overall CO_2 emission worldwide in 2014. The transportation emission has a higher share than the world average value in all the selected regions except China and Iraq.

The industrial sector contributed by about 19 % of the overall CO_2 emission worldwide in 2014. Only China and Brazil have higher CO_2 emission in their industrial sector than the world average value among the selected regions. China is the highest emitter from the industrial sector which was responsible for about one third of its overall emission in 2014.

The rest of sectors combined, emitted about 10 % of overall CO_2 emission worldwide in 2014. USA, Italy, Algeria and Illinois have a higher emission than the world average value, while other regions were below the world emission level in the rest of sectors combined.

2.2.2. Emission per kWh

We calculated the amount of CO_2 emission per unit electricity in the Algeria, Australia, Brazil, China, Illinois, Iraq, Italy, USA and worldwide for the period 1990 to 2014 and and we report the result in g/kWh in Figure **3**.

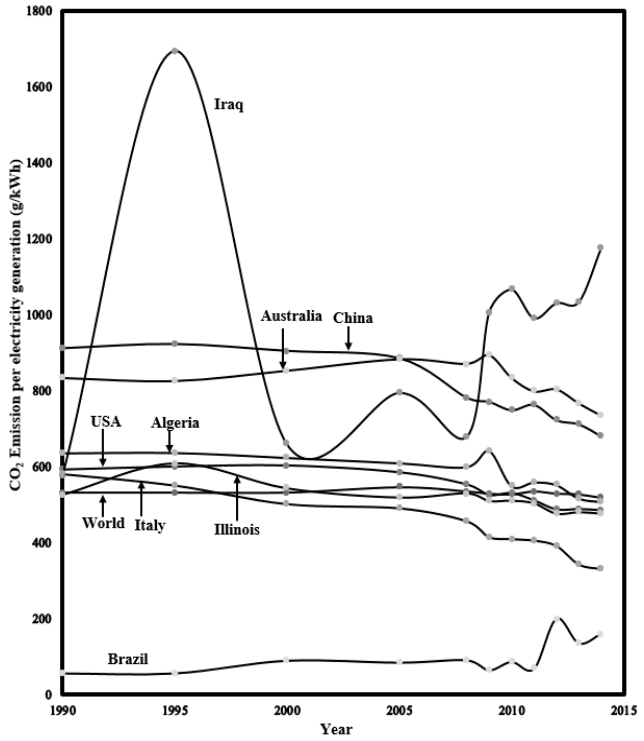

Figure 3: Amount of CO_2 emission per unit electricity in [g/kWh] for the world, seven ountries and State of Illinois, USA in the 25 year period 1990-2014 (Data from [10]).

By examining Figure **3** we make the following observations:

CO_2 worldwide emission per kWh of electricity generation has decreased about 20 [g/kWh] in the 25 year period which may be atributed to advances in more efficient energy conversion technoliges and/or the more use of renewable energies. CO_2 emission per kWh in the developing countries (Algeria, China, Iraq) was higher than the developed countries, except for Auslteria, in the 25 year peroid 1990-2014. Australia emission per unit electricity exceeded China starting with 2005. Even though Brazil's CO_2 emission per kWh has almost triples in 25 years, it is far lower than the other selected regions. The low value of the emission per electricity unit in Brazil is due to the high level of hydropower utilization for electricity generation. Furthermore, all of the selected regions emission has decreased in 25 years except for Iraq and Brazil, which has increased by about 51% and 180%, respectively.

The electricity production in China is one of the major sectors associated with CO_2 emission around the world. Although, the g/kWh of the China's emitted CO_2 has decreased in 25 years, it is still higher than the value in the world and all other counties except Australia. Italy's CO_2 emission per kWh has decreased by a rate of more than any other region. Iraq's CO_2 emission per kWh has almost tripled in 25 years with a sharp fluctuation during this period due to possibly the variation in the amount of generated electricity in the studied period. However, it is still below Iraq demand, and its worth to mention that Iraqi citizen did not get 24 hours of electricity per day during the last four centuries. Illinois has the lowest CO_2 emission per kWh among the selected regions.

2.2.3. Emission per Capita

In Figure **4** we report CO_2 emission per person per year (per capita) in the world, seven countries and State of Illinois, USA in the 35-year period of1980 to 2014.

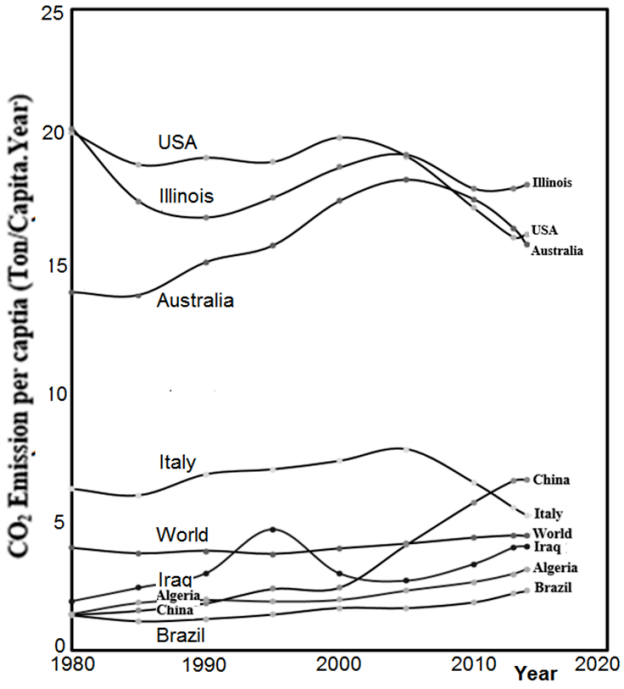

Figure 4: CO_2 emission per person per year (per capita) in the world, seven ountries and State of Illinois, USA in the period 1980 to 2014 (Data from [10]).

We make the following observations from Figure 4: During the 35-year period 1980-2014, the World emission per capita has increased slightly, mostly because of the rise in the world population. CO_2 emission per capita has decreased in the developed countries, except in Australia, while it has increased in the developing countries. USA and Australia have the highest CO_2 emission per capita and Brazil has the lowest. China's CO_2 emission per capita has been increasing with a fast rate since the year 2000, while Italy has had a fast rate of decrease in CO_2 emission per capita since 2005.

It can be also noticed that all the developed countries have higher CO_2 emission per capita than the world average value. Moreover, the value of USA, Illinois and Australia is much higher the world value. On the other hand, all the developing countries, except China since 2005, have a lower value than the world average.

2.2.4. Emission per GDP

CO_2 emission per GDP is a measure of the emission intensity per unit of economic activity of various countries. In Figure **5** we report emission amount per GDP using exchange rates based on 2010 U.S. dollar in the world, seven ountries and State of Illinois, USA for the 15-year period 2000 to 2014.

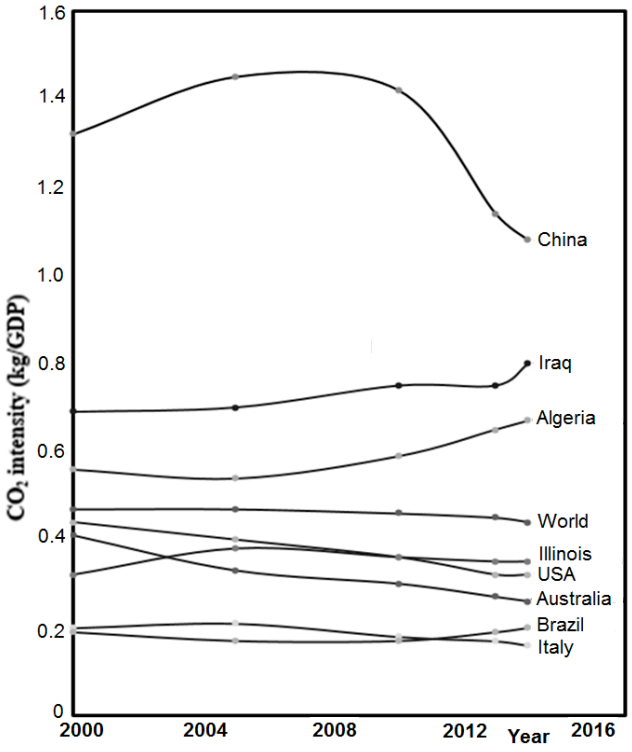

Figure 5: The emission amount per GDP using exchange rates based on 2010 U.S. dollar in the world, seven ountries and State of Illinois, USA for the 15-year period 2000 to 2014. (Data from [10]).

GDP could be expressed by multiple way such as national currency, US dollar or purchasing power parity. Here we used 2010 U.S. dollar to represent the GDP using exchange rates. As shown in Figure 5, countries have a difference emission per unit economy. CO_2 emission per GDP in the developing countries, except Brazil, are generally higher, than those of developed countries in the 15-year period between 2000 and 2014. Also, he numbers for developing countries has kept increasing while those of developed countries keep decreasing. The world CO_2 emission per GDP remains quite constant and lies in between the developed and developing countries. China's CO_2 emission per GDP is much bigger than all the other selected regions and it has changed more in the 14-year period.

There is a wide difference in the emission intensity between the countries due to change in shifts in energy intensity, economic structure and fuel mix [18].

$$CO_2 \text{ intensity } \frac{CO_2}{GDP} = \text{Energy intensity } \frac{Energy}{GDP} \cdot \text{Fuel mix } \frac{CO_2}{Energy} \quad (1)$$

The carbon dioxide intensity depends on two factors: the energy intensity and the fuel mix. The energy intensity is the amount of the energy consumed per unit of GDP. The energy intensity reflects both the efficiency of the energy and the country's economic structure, including the carbon content of the imported and exported goods. The economy that is dominated by heavy industrial production is more likely to have higher energy intensity than one that is dominated by service sector. The developing countries tend to have higher energy intensity and carbon dioxide intensity since large contribution of their GDP comes from energy intensive industries. For example, China, Algeria and Iraq have higher CO_2 intensity than USA, Australia, Italy and Illinois.

The other factor is the carbon content in the consumed fuel, or fuel mix. Per equation (1), if, for example, three countries have the same energy intensity but the first country relies on coal, the second country relies on oil and the third country relies on natural gas as energy source, CO_2 intensity will be higher in the first country that relies on coal, followed by the second country that relies on oil and the third county that relies on natural gas. Coal emits more CO_2 per unit of its energy utilized than oil and oil emits more CO_2 per unit of its energy utilized than natural gas.

2.3. Future of Emissions

The world CO_2 energy-related emission is expected to increase from the current levels to 35.6 gigatons of CO_2 in 2020 and to 43.2 gigatons of CO_2 in 2040 [19] as shown in Figure **6**.

The largest portion of this increase attributed by the developing countries which will continue relying on fossil fuels as a main energy source. In 2040, the developing countries outside the Organization of

Economic Cooperation and Development (OCED) are estimated to emit CO_2 higher than 2012 levels by 51% while OCED counties will emits only 8% higher than 2012 levels [18]. Coal, which is became the leading-source of energy CO_2 emission in the world in 2006, will remain as number-one energy source through 2040 by a share of about 38%. The natural gas emission share will increase to 26% in 2040. The expected increase in energy related CO_2 emission is due to increase in the energy derived from fossil fuels. The energy produced from the fossil fuels is expected to increase by 177 quadrillion Btu in 2040 above 2012 levels. Coal use are expected to decrease from 28% in 2012 to 22% in 2040, while natural gas share will increase from 23% in 2012 to 26% in 2040.

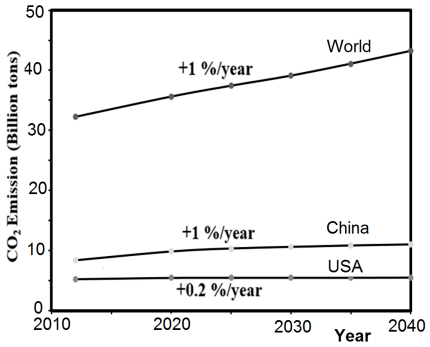

Figure 6: CO_2 emission in World, U.S. and China during the period 2012-2040.

U.S. emission is planned to be reduced by 0.5 gigatons of CO_2 in 2040 below 2012 levels. U.S. has announced to reduce its emission by 17% below 2005 levels in 2020 and by 26-28% in 2025. The decrease in U.S. emission will come from the reduction of using the fossil fuels and installing renewable energy projects. U.S. is planning to install 101, 101, 102, 102 and 105 gigawatts nuclear projects in 2020, 2025, 2030, 2035 and 2040, respectively. The hydroelectric and other renewable projects are planned to be 301 gigawatts in 2040 with a growth rate of about 1.8% from 2011 to 2040.

The U.S. Environmental Protection Agency (EPA) finalized a Clean Power Plan (CPP) to reduce the electricity production from fossil fuels by increase the dependence on the renewable energy projects, fuel economy improvements and raise the efficiency of the industrial processes. The United States set a goal in 2005 to reduce the emission by 17% in 2020 of what it was at 2005 [18].

China, the largest developing country, emits enormous amounts of CO_2 currently and will continue in the next 15 years. China's emission will account for about 27% of the overall world emission in 2030 comparing with less than 8% in 1980 [18]. China is expected to hit the emission peak in 2030, and try to achieve this peak earlier. It is proposed to a target of 20% non-fossil fuels energy in 2030. If China's total emission are to maximize at 2030, coal consumption will have to stop increasing, and decrease substantially, between 2015 and 2035 unless carbon capture and sequestration is rapidly modified. Since the energy demand of China's middle class will keep growing, the contribution of the energy consumption is expected to keep shifting from industry to the building and transportation sectors. The energy efficiency of the building and the transportation sectors improved in the recent years.

China's coal consumption is expected to increase by a rate of 0.3% from 2012 to 2040. The coal consumption is expected to be about 83.3 quadrillion Btu in 2040 with an emission from the used coal about 7.4 gigatons of CO_2. The nuclear installed projections are expected to increase by 9.2 between 2012 and 2040 to reach 152 gigawatts.

China put more than one project and policy to achieve the emission mitigation goal. One of the projects is the 12^{th} Five-Year-Plan which is published in 2011. It states that a decrease of CO_2 emission intensity by unit GDP by 17% will be achieved between 2011 and 2015, using alternative energy resources from 8.3% in 2010 to 11.4% in 2015, decrease the power consumption by 16% between 2011 and 2015 and increase the forestry of the land by 0.6 m^3. The 12^{th} Five-Year Plan for renewable energy development includes increasing the use of the renewable energy to 1400 gigawatts by 2030. Energy Development Strategy Action Plan is another plan that assumes an increase in the gas usage as a fuel by 10% in 2020 and reduce the coal consumption [20].

There is not much information about the emission future predictions in Iraq. However, the exist references estimates that the electricity generation in Iraq increases will increase from 16 gigawatts in 2010 to 60 gigawatts in 2020 and to 83 gigawatts in 2035. There will be no shift from fossil fuels technologies to the renewable ones, so CO_2 emission is expected to increase in the following years [21].

Illinois is planning to reduce the emission from the power from 96.1 gigatons of CO_2 in 2012 to 67.2 $GtCO_2$ in 2030 [22]. There are many paths for Illinois to

achieve its goal of reducing the emission. One of the ways is the energy efficiency, doing more and using less, which is the most cost-effective way. Another way is to use additional renewable energy sources such as wind and solar which assumed to produce $19x10^9$ kWh annually by 2030.

3. GLOBAL WARMING DUE TO CARBON DIOXIDE

CO_2 is a greenhouse gas and its increase in the atmosphere has been contributing to the global warming [23]. The evidence that supports global warming includes the alarming rate at which continental glaciers in Greenland and West Antarctica are melting [24]. Also, killer heat waves have been attributed to global warming and were blamed for hundreds of human deaths in Illinois in 1995 and over 70,000 deaths in Europe in 2003 [25, 26]. According to climatologists, the 5-day heat wave which engulfed Illinois and other Midwestern states during mid-July 1995 were one of the worst weather-related disasters in the history of Illinois. It caused 581 deaths in Illinois while the City of Chicago suffered the most with 525 deaths [25]. January 2014 was the fourth warmest January around the world since global temperature records began in 1880, while the coolest was January 1893.

Measurements indicated an increase of 0.3-0.6°C (0.54-1.08 ^oF) in global temperatures during the 20^{th} century. If the trends in emissions of greenhouse gasses continue, there is a possibility that the global mean temperature by the end of the 21^{st} century will be 3^oC higher than its current figure [27].

Vegetation (Plants and trees) play a critical role in the carbon cycle, maintaining safe levels of carbon dioxide (CO_2) and oxygen (O_2) in the air, water, and environment for millions of years (see Figure **7**).

The balance of oxygen and carbon dioxide in the environment has maintained through respiration and photosynthesis in trees and plants, which played a major role in addressing climate change. Also, the natural formation of carbonate minerals in the Earth crust, as well as CO_2 uptake by the oceans are the additional processes sustaining the long-term global carbon cycle [13, 28]. According to a 2013 U.S. Congressional Service Report [25], during the 1990s about 45% of the CO_2 emissions from fossil fuels combustion and land use activities has remained in the atmosphere, with the balance taken up by the oceans, vegetation, or soils on the land surface. Because of an excessive amount of CO_2 being released into the atmosphere from fossil fuels combustion, the role of plants and trees in maintaining the global climate is minimized.

To avoid environmental disaster, human intervention is required to improve the way energy is produced and consumed [29]. These include scientific and engineering approaches that are intended to significantly reduce emissions of greenhouse gasses, more utilization of renewable energy sources and carbon dioxide capture and sequestration, with the aim of stabilizing atmospheric CO_2 concentrations at 550 ppm by 2025 [30, 31]. Reducing carbon dioxide released into the atmosphere would reduce, and perhaps reverse, the effects of global warming that we have been experiencing in the last several years.

Although electricity generation using conventional coal-fired power plants is a matured industry, there remain several obstacles when connecting this conventional process with carbon dioxide capture technology. Among the obstacles are the high capital cost of carbon dioxide capture technologies (with approximately 75% increase in capital cost for adding carbon dioxide capture equipment), a large footprint required for carbon dioxide capture equipment, operational problems and a high energy penalty for carbon dioxide removal from flue gases in absorption columns using liquid solvents and regeneration of absorbing solvents [32].

4. CONCLUSIONS

CO_2 emission from fossil fuels combustion has increased significantly during the last century above the preindustrial levels. Thus, the concentration of CO_2 in the atmosphere exceeded the safe level, which has caused an increase in the Earth's temperature. Worldwide CO_2 emission from fossil fuels combustion has almost doubled during the past 35-year period and the atmospheric concentration reached about 404 ppm in 2016.

We have studied and compared, in several new and unique ways, the CO_2 emission in selected populated countries in all continents, which are known as highly active in fossil and/or renewable energy production / use. They included Algeria, Australia, Brazil, China, Iraq, Italy and USA. We also included the State of Illinois, USA, which is the outmost active state in fossil and renewable energy production and use, and is a pioneer state in dealing with carbon dioxide control and

sequestration. By comparing the selected regions with the related data of the entire world, showed interesting trends in carbon dioxide emission as it related to the four variables (per sector, per kWh electricity production, per capita, and per GDP). Our analysis revealed a great deal about the activities going on around the world. This may provide policymakers and environmentalists a more proper roadmap in dealing with carbon dioxide emission control policy and planning.

The analysis reported here is a preliminary observation made by looking at the data for the world. A comprehensive analysis of the whole world data with predictive capability is the subject of our GAM.UIC.CO2 Package Database under contract with our sponsors.

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